Fast Cycling SC Magnets

Participants

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Gebhard Moritz- Magnet System

Al McInturff- Quench protection

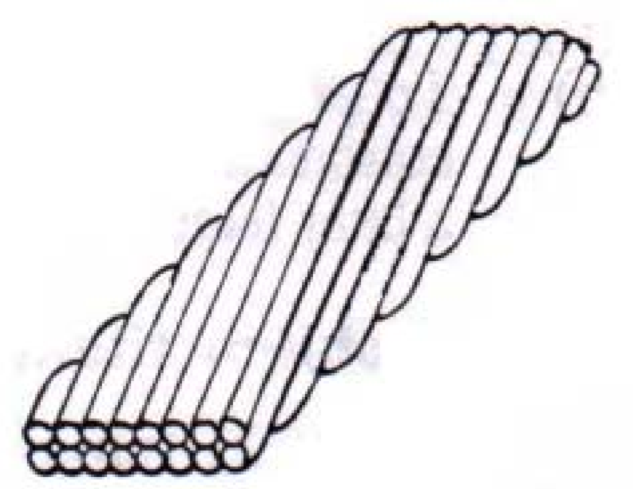
Workshop Plans

- Issues for SC magnets operating at 1Hz
  - Optimal conductor choice
  - Warm or cold iron
  - Maximum field range ? (SIS 300 ⇨ 6T)
  - Quench Protection
  - Effect of Cyclical Stress in the Coil
    - Mechanical Stability of the Nuclotron Coil package including ends
  - Field Harmonic measurements
    - Not addressed at this workshop. BNL is working on a measurement system described in MT-18
- Present Status

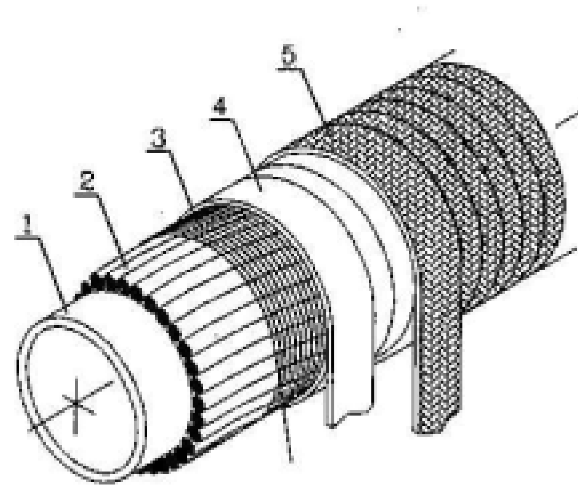
Starting Point for Magnets

- SIS100 ring cycling to 2T at 4T/s
  – Nuclotron Magnet
  – Iron Dominated
- SIS200 ring cycling to 4T at 1T/s
  – GSI-001 RHIC style Magnet
  – Coil Dominated
- SIS300 ring ramped up at 1T/s to 6T
  – UNK magnet at 5T
  – SSC magnet at 6.6T
  – Single bore LHC magnet

Conductor/ Cable Design



Rutherford



Nuclotron

1-Cooling tube

2- Sc. strands

3- Nichrome wire

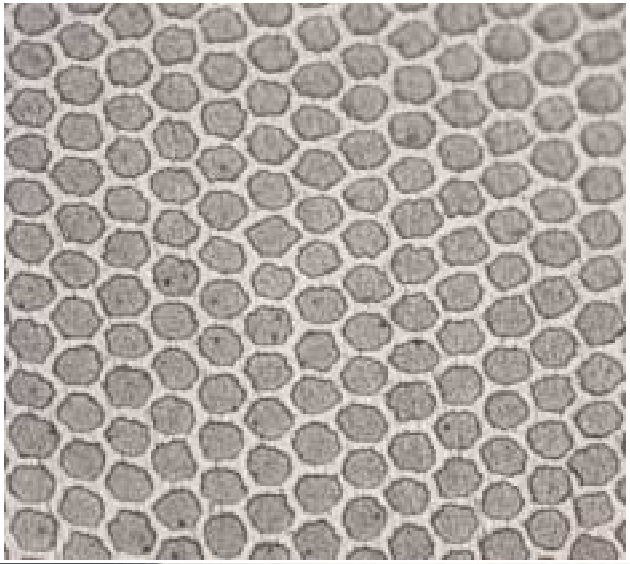
4- Kapton tape

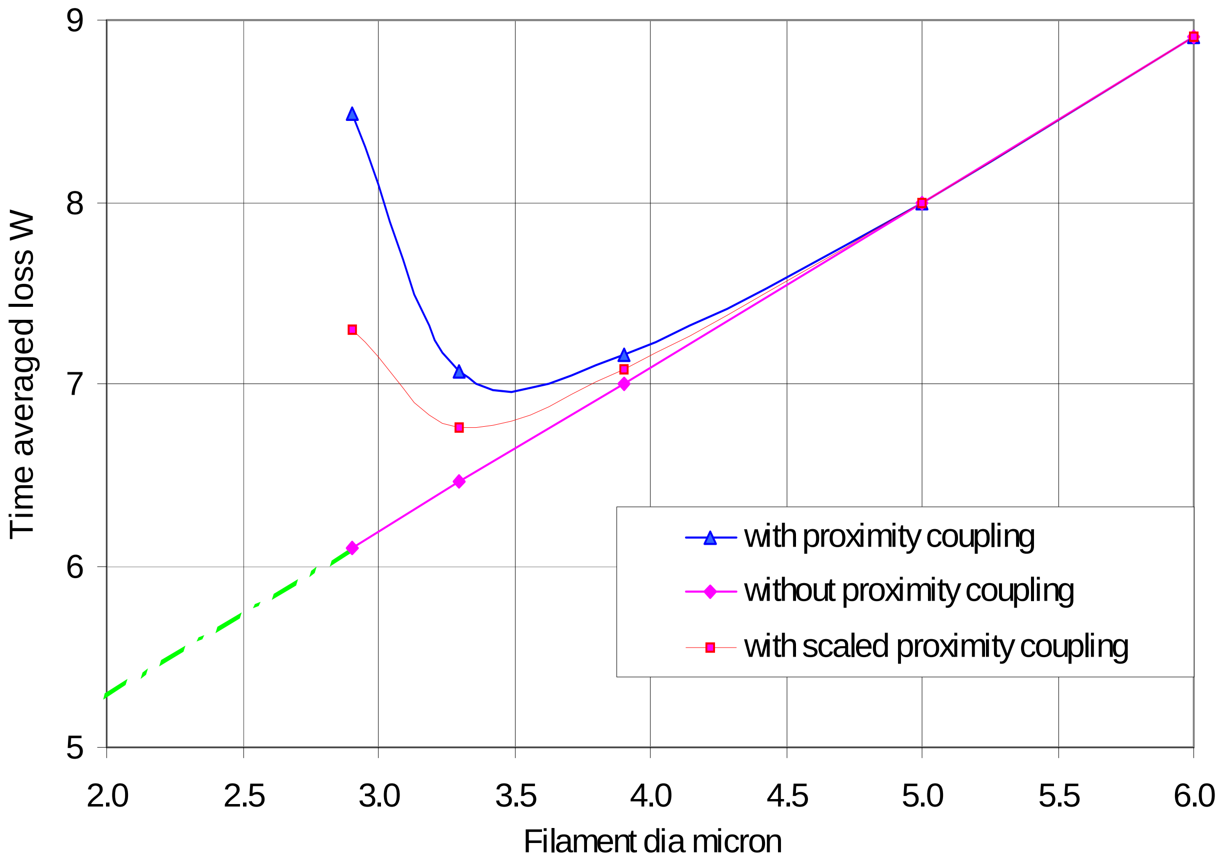
5 Glassfiber tape

For Cos θ Magnet :Strand Design

- Minimize SC magnetization
  - Small filament diameter 2.5 μm
  - suppress “proximity-coupling by using Cu-2.5%Mn matrix.
- Reduce eddy-current magnetization
  - High-resistive matrix, Cu-2.5%Mn
  - Small twist pitch, practical limit 5xD
  - Jc > 2500 A/mm^2 at 5T

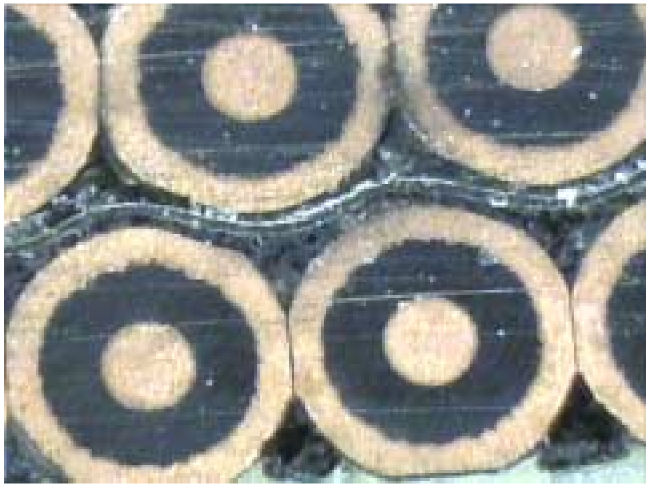
Scaling of loss with filament diameter

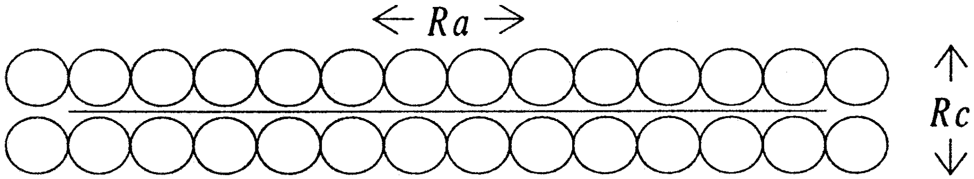




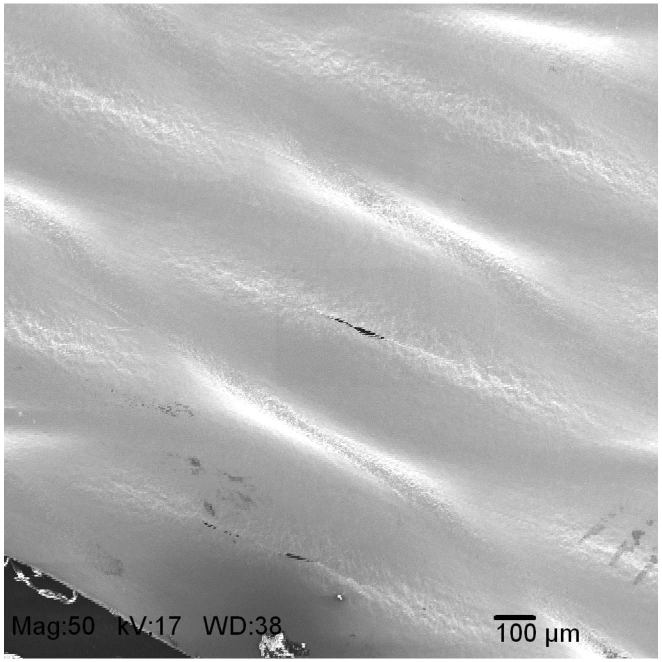
dB/dt Magnetization in a Rutherford Cable

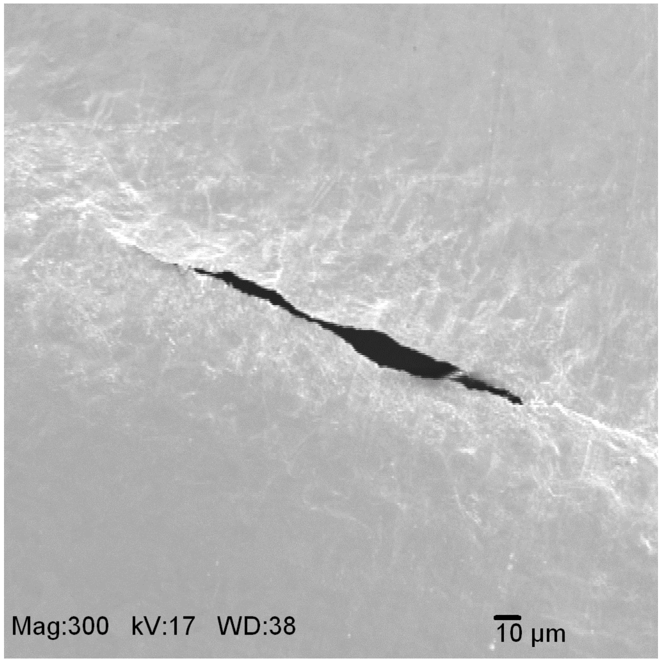
- **2 layers of 25 μm SS tape works well to eliminate Rc eddy-current effects. *Cabling experience limited* . Single layer core material options is under study.**
- **Keep R_A low for adequate Current Sharing. Ag-Sn coated strands works well**





Perforations in the SS-ribbon at the cable minor edge





Cable made with 50 µm brass ribbon as a core does not show any pin-holes..

Loss contributions at 1T/s for GSI-001 Prototype Magnet

transverse crossover loss (R_C)	= 0.33%
transverse adjacent loss (R_A)	= 7.3%
parallel loss (Rc)	= 0.14%
filament coupling loss (Cu-matrx)	= 29.6%
hysteresis loss (d_{fil} 6 μm)	= 62.6%

These are based on measured strand and cable properties

From measurements of the 4T BNL magnet:Conclusions by M. Wilson

➔Theory works pretty well!
➔Good enough to design magnet cooling and refrigeration
➔Rate dependent losses show anomalous increase at high fields
    ➔change in R_A with increasing pressure?
➔Hysteresis losses show anomalous increase at high fields
    ➔iron?
    ➔transport current?
    ➔movement + friction?

Quench protection issues

- SIS 100 design can use the sextant dump but with the protection resistor to 0.08 ohms and cold diodes, or
- if the machine is divided into thirds then the protection resistor at 0.16 ohms will drive the magnet to 300K or cold diodes have to be used.

Quench Protection SIS 200

- 4T magnet at 1T/s
- using“100” Design - 1/3rd ring dump scheme
- A 120 magnet circuit ~2 mH/magnet
- 40 magnets/string R_p = 0.16 ohms
- I(oper) = 6 kA V(max) = 960 volts
- --> 80mH/0.16 ~0.5 sec.
- ---> RHIC Miits curve T(max) ~300K
- ---> peak voltage to Grd <1.4kV

Quench Protection Issues

- If we use cold diodes
- Ramp rate 1 T/sec or 1.5kA/sec   --> 4T
- diode turn-on V $2x10^{-3}$ x $1.5x10^{3}$ = 3volts
- at 1.3V (LHC type diode) need a stack of three diodes/magnet

Quench protection SIS 300

- 6T magnet
- For operating currents less than 7 kA, combination of diodes and extraction/or bypass (SCR)
- For options over 7kA operating current, the number of diodes doubles but the number of circuits needed (assuming V_{limit} of 1.5 kV to ground) is similar, major sections separated by SCR's opening main circuits at each magnet protection string.

Summary

- SC magnets cycling at 1-4T/s are quite feasible.
- Develop strand with smaller filament size 2.5-3.5 µm goal. Nb_3Sn as an option ?
- Development of single tape“cored” cable
- Examine the mechanical constraint of the coil and the ends for the Nuclotron magnet
  - quench protection choice
- For SIS 300 examine the different available designs for cost, reliability, quench protection

Write-up

- Conductor and cable development
  - Arup Ghosh
- Magnet system for SIS 100 and SIS 300
  - Gebhard Moritz
- Quench protection of SIS 100 and SIS 300
  - Al McInturff